Late Results of Aortic and/or Mitral Valve Replacement : Factors Influencing Long-term Functional Status

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Summary

The factors influencing long-term functional status after aortic and/or mitral valve replacement were examined in 67 patients who survived for at least one year after surgery. An analysis of the possible factors in the preoperative, intraoperative and postoperative periods shows that the preoperative duration of symptoms, the presence of coexisting valvular disease, atrial fibrillation and thromboembolism are significant contributors to a poor prognosis. Coexisting valvular lesions, such as tricuspid insufficiency and mitral insufficiency, frequently progress postoperatively, and their treatment remains palliative. Myocardial dysfunction is considered to be an additional factor responsible for poor results following the successful correction of the mechanical defects. It is emphasized, therefore, that earlier operation, prior to the development of myocardial dysfunction, is necessary to improve functional results after valve replacement.

Introduction

Recently, valve replacement has provided a striking advance in the treatment of patients with valvular heart disease and has saved many lives. Although the long-term results of valvular heart surgery have been evaluated from various aspects, the postoperative quality of life, which is the most important consideration in surviving patients, has not been extensively discussed. The ultimate goal of valve replacement should be to enable a patient

Key words : Late result of valve replacement, Postoperative functional status, Coexisting valvular disease, Radiocardiography, Myocardial dysfunction.
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with valvular heart disease to lead an active and useful life with no symptoms (New York Heart Association, NYHA, Class I). From this point of view, improvement to NYHA Class II is not yet satisfactory, and the current results at most centers are still far from ideal.

This report will attempt to define factors preventing complete recovery (NYHA Class I) following valve replacement.

Method of study

A total of 87 patients underwent aortic and/or mitral valve replacement between May, 1965 and September, 1979 (tricuspid valve replacement excluded). Of the 67 patients who survived for more than one year, 64 (95.5%) have been followed in clinic visits or by a mail survey. The follow-up period ranged from one to 14 years (mean 6.75 years). Twenty-nine had aortic valve replacement, 28 had mitral valve replacement and seven had double valve replacement. Patients' ages were nine to 60 years (mean 31.5 years). There were 42 males and 22 females. The preoperative NYHA classification was 17 (26%) in Class II, 44 (69%) in Class III and three (5%) in Class IV. The diseases requiring aortic valve replacement were aortic insufficiency in 26 patients (72%), aortic stenoinsufficiency in eight, and aortic stenosis in two, and those needing mitral valve replacement were mitral stenoinsufficiency in 22 (63%), mitral insufficiency in 10 and mitral stenosis in three. The postoperative functional status was determined in a recent follow-up investigation. Fifty-nine survivors were divided into two groups according to their functional status : Group A, NYHA Class I (29 patients); and Group B, NYHA Class II-IV (30 patients).

Surgical procedures: For aortic valve replacement, coronary perfusion was utilized during implantation of the prosthesis in all except the last two cases in which cardioplegic arrest was used. Aortic valve substitutes were Starr-Edwards prosthesis (18 cases), Björk-Shiley prosthesis (11 cases), Lillehei-Kaster prosthesis (5 cases) and homograft (2 cases). Mitral valve replacement was performed without anoxic arrest except for simple anoxic arrest in seven and cardioplegic arrest in two cases. The mitral valves implanted were Starr-Edwards prosthesis (24 cases), Björk-Shiley prosthesis (4 cases) and Lillehei-Kaster prosthesis (7 cases). Double valve replacements were done by combinations of the above procedures, using the same type of prosthesis for the aortic and mitral positions. Mitral valve commissurotomy (9 cases) and tricuspid annuloplasty (7 cases) by Boyd's method were sometimes added to valve replacement.

Hemodynamic evaluation by radiocardiography : The method of analog simulation analysis of radiocardiography has been reported in detail elsewhere[16].

In brief, the circulatory system was theoretically divided into four compartments, right heart, lung, left heart and body, connected in series. Each chamber was treated as a single mixing chamber with a transport time delay in lung and body. The theoretical radiocardiogram was compared with the patient's radiocardiogram and the best fit of the two radiocardiograms was done by trial-and-error, adjusting various parameters of the circuit. Among the many variables obtained, cardiac index, right and left heart volumes and mean

pulmonary circulation time were examined in this study.

Result

The overall results are summarized in Table I. There were five late deaths, three due to prosthesis-related causes (Table II). Cummurative survival and symptom-free (NYHA Class I) curves based on valve position are shown in Fig 1. Approximately 70% of the patients could return to NYHA Class I immediately after surgery, but the rate gradually decreased to 50% at five years and only 40% at 10 years. Neverthless, 75% of the patients improved by at least one functional class, although one third of them remained in Class II. Group A and Group B were compared as to possible factors influencing postoperative functional recovery. Preoperative duration of symptoms, the presence of associated valvular disease and atrial fibrillation showed statistically significant differences between the two groups (Table III). Associated valvular diseases appeared to have the greatest effect on the results of valve replacement if they had been present for a long time and if there was atrial fibrillation (Table IV). The follow-up period for Group A (5.4 years) was significantly shorter than that for Group B (8.4 years). This suggests a tendency to late deterioration

Table I Overall results in patients who survived at least one year. AVR : aortic valve replacement, MVR : mitral valve replacement, OMC : open mitral commissurotomy, TAP : tricuspid annuloplasty.

Procedure	No. of case	Postoperative NYHA class			Late death
		I	II	III-IV	
AVR	20	12	6	0	2
AVR+OMC	9	2	5	1	1
MVR	23	10	6	6	1
MVR+TAP	5	2	2	1	0
AVR+MVR	6	3	2	0	1
AVR+MVR+TAP	1	0	0	1	0
Total	64	29 (45%)	21 (33%)	9 (14%)	5 (8%)

Table II List of late deaths. SE : Starr-Edwards.

Case	Procedure	Cause of death	Postop. period (yrs.)
1	AVR (SE valve)	Renal failure	1.3
2	AVR+MVR (SE valve)	Clotted valve	1.6
3	AVR (SE valve)	Subacute bacterial endocarditis	4.5
4	AVR+OMC (homograft valve)	Malfunction of homograft	7.0
5	MVR (SE valve)	Sudden death due to unknown cause	8.7

Table III Comparison of possible preoperative factors in Group A (NYHA Class Ⅰ) and Group B (NYHA Class Ⅱ-Ⅳ).

Group	Procedure	No. of case	Age (yrs)	NYHA class	Duration of symptom (yrs)	Associated valve disease	Atrial fibrillation	CTR	Cardiac index	LVEDP	PC wedge pressure
A	AVR	14	30 (±13)	2.64 (±0.74)	5.9 (±5.8)	2 (14%)	0	0.60 (±0.06)	3.17 (±1.10)	17.8 (±13.2)	14.7 (±7.3)
	MVR	12	29 (±12)	2.92 (±0.29)	3.2 (±3.0)	5 (42%)	6 (50%)	0.62 (±0.08)	2.58 (±0.69)	11.2 (±4.78)	21.4 (±8.3)
	AVR+MVR	3	36 (±11)	2.33 (±0.58)	11.0 (±4.3)	—	0	0.64 (±0.10)	3.80 (±1.62)	16.5 (±3.54)	14.3 (±9.3)
	Total	29	30 (±12)	2.72 (±0.59)	5.3 (±5.3)	10 (34%)	6 (21%)	0.62 (±0.07)	3.06 (±1.15)	15.6 (±10.3)	17.7 (±8.55)
B	AVR	12	34 (± 6)	2.67 (±0.49)	12.4* (±7.6)	9 (75%)**	6 (50%)**	0.58 (±0.05)	2.70 (±0.80)	13.0 (±2.45)	16.9 (±6.0)
	MVR	15	32 (±11)	2.87 (±0.52)	7.1* (±4.3)	11 (73%)	13 (87%)	0.60 (±0.10)	2.67 (±0.85)	9.0 (±3.53)	19.1 (±6.4)
	AVR+MVR	3	30 (±14)	3.00 (± 0)	7.3 (±7.8)	—	2 (67%)	0.67 (±0.07)	2.55 (±1.20)	12.0 (±2.65)	19.7 (±1.5)
	Total	30	33 (±10)	2.80 (±0.48)	9.3** (±6.5)	23 (77%)**	21 (70%)**	0.60 (±0.08)	2.67 (±0.83)	10.9 (±3.48)	18.3 (±5.84)

* $p<0.05$ ** $p<0.01$

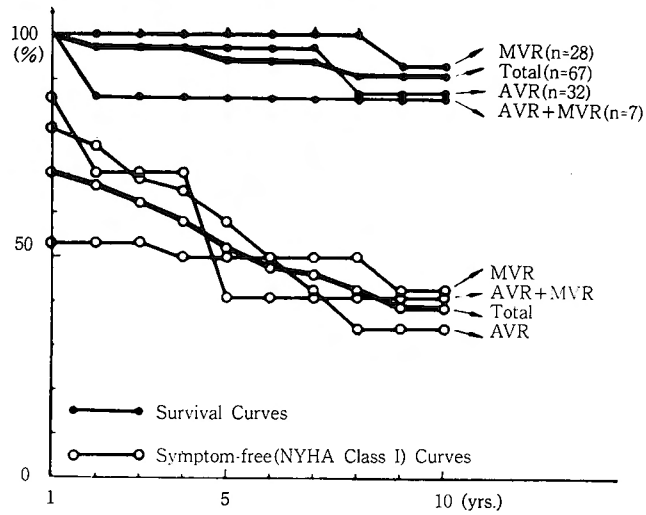

Fig. 1 Survival and symptom-free (NYHA Class I) curves based on valve position. Operative deaths are excluded in this figure.

Table IV Comparison of factors in Group A and Group B patients with combined valvular diseases.

Group	No. of case	Age (yrs)	NYHA class	Duration of symptom (yrs)	Atrial fibrillation	Cardiac index	Postop. period (yrs)
A	11	32 (±11)	2.64 (±0.50)	6.3 (±5.5)	3 (27%)	2.87 (±1.12)	5.4 (±3.5)
B	23	33 (±10)	2.87 (±0.46)	10.7* (±6.1)	19 (83%)**	2.57 (±0.83)	8.4* (±4.0)

* : $p<0.05$ ** : $p<0.01$

in combined valvular disease. On the other hand, none of the surgical factors examined provided significant effects on the results, except topical cooling (Table V).

The survival and symptom-free curves of cases of isolated and of combined valvular disease are shown in Fig 2. Of the patients with combined valvular disease, 60% returned to Functional Class I soon after valve surgery but 10 years later only 20% were in Class I. This poor result did not depend on whether or not complete repair was achieved (Table VI). On the other hand, there was no significant difference in the survival rates of those with isolated or combined valvular diseases.

The functional status of 18 patients (31%) deteriorated during the follow-up period (Fig 3). Eleven of them may have had progression of coexisting or of newly developed valvular lesions. Especially mitral valve disease and tricuspid insufficiency, whether corrected or not, appeared to be significant contributors to late deterioation. However, aortic

Table V Comparison of Group A and Group B as to surgical factors influencing myocardial protection.

Group	Procedure	No. of case	Bypass time (min)	Anoxic arrest (min)	Assisted circulation before weaning off bypass (min)	Use of topical cooling
A	AVR	14	173 (±66)	11 (± 8)	25 (±27)	8 (57%)
	MVR	12	138 (±51)	46 (±22)	16 (± 9)	3 (25%)
	AVR+MVR	3	259 (±54)	9 (± 2)	52 (±38)	2 (67%)
	Total	29	167 (±67)	18 (±18)	24 (±24)	13 (45%)*
B	AVR	12	186 (±35)	16 (±17)	35 (±14)	3 (25%)
	MVR	15	129 (±25)	25 (±11)	17 (± 6)	2 (13%)
	AVR+MVR	3	288 (±79)	?	63 (±18)	1 (33%)
	Total	30	168 (±60)	25 (±25)	27 (±17)	6 (20%)

* : $p<0.05$

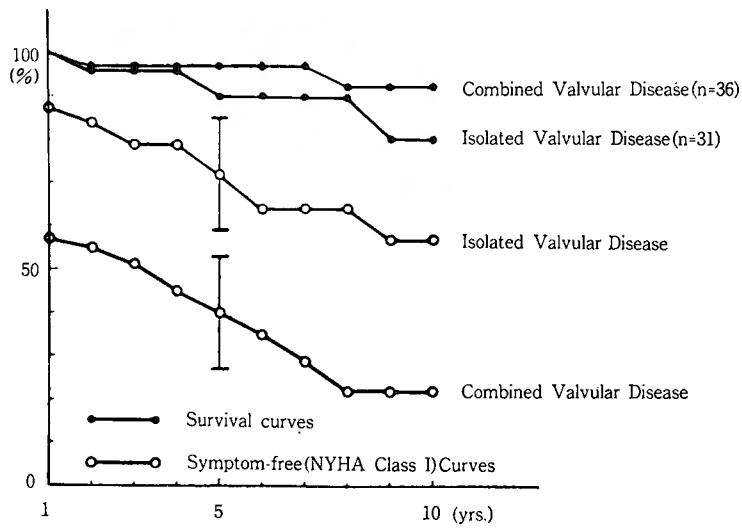

Fig. 2 Survival and symptom-free curves in isolated and combined valvular diseases. Operative deaths are excluded in this figure.

insufficiency did not seem to be a factor. Other probable causes were thromboembolism in three cases and coronary artery disease in two. The cause was unknown in two cases.

Of the 64 patients who survived at least one year after surgery, thromboembolism occurred in 13 in spite of anticoagulant therapy (Fig 4). Atrial fibrillation was present in 10 patients. Although embolic episodes were relatively common early in the postoperative period, only patients with a Starr-Edwards noncloth covered prosthesis in the mitral position

Table VI Effects of coexisting valvular lesions on postoperative functional results.

Associated valvular lesion	Procedure	No. of case	Group		Deterioration p surgery
			A	B	
Aortic insufficiency	Uncorrected	7	2 (29%)	7 (71%)	0
Mitral stenosis	Commissurotomy	8	2 (25%)	6 (75%)	1 (13%)
	Uncorrected	2	1 (50%)	1 (50%)	1 (50%)
Mitral insufficiency	Uncorrected	3	0	3(100%)	2 (67%)
Tricuspid insufficiency	Plasty	6	2 (33%)	4 (67%)	2 (33%)
	Uncorrected	8	1 (12%)	7 (88%)	4 (50%)
Total	Corrected	14	4 (29%)	10 (71%)	3 (21%)
	Uncorrected	19	4 (21%)	15 (79%)	6 (32%)

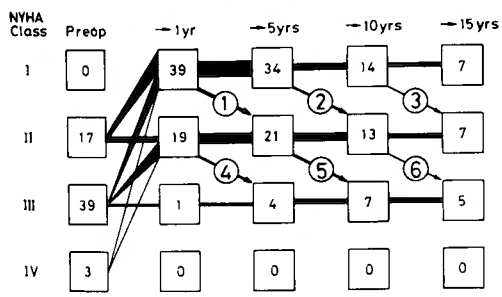

Fig. 3 Changes of functional status during follow-up period. Six degrees of deterioration are diagrammed (1-6) and their causes are listed in the table right.
"*" : In one case it developed only after surgery.

Position's number	Cause of deterioration	No. of case
1	Mitral insufficiency ↑	1
	Mitral stenosis ↑	1
	Thromboembolism	1
	Coronary artery disease	1
	Unknown	1
2	Mitral insufficiency ↑	1
	Mitral stenosis ↑	1
	Coronary artery disease	1
3	Thromboembolism	1
	Unknown	1
4	Tricuspid insufficiency ↑	3
5	Tricuspid insufficiency ↑	2
	Thromboembolism	1
6	Tricuspid insufficiency ↑	2 *

had emboli more than 10 years later.

The changes of cardiac index, right and left heart volumes and pulmonary circulation time were followed by radiocardiography pre- and postoperatively at various intervals (Fig 5 and 6). In Group A patients with either isolated or combined valvular diseases all parameters returned to normal soon after surgery and remained within normal limits thereafter. In Group B some improvement was obtained in each parameter, but the values were still abnormal. It is remarkable that the cardiac index of Group B patients with isolated

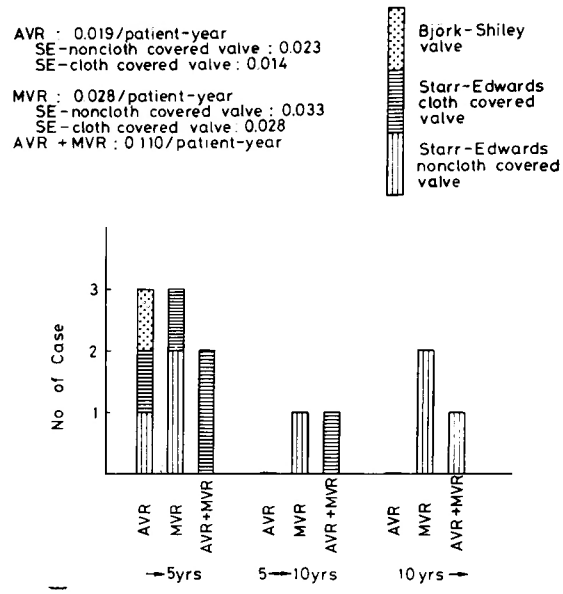

Fig. 4 Thromboembolism according to valve position, type of prosthesis and time of onset. Incidence of embolic episodes (above), calculated per patient-year, related to valve position.

valvular disease and no other obvious defects could not rise postoperatively. This failure might be due to myocardial dysfunction. In combined valvular disease, complete repair tended to produce better results, especially in the cardiac index, early in the postoperative period. In a few years, however, all parameters progressively worsened, and there were no differences between cases of complete and incomplete repair five years later. Extremely high values of heart volume were considered to be due to volume overload produced by progression of coexisting valvular lesions. Multivariable patterns of the latest data in each patient demonstrated specific changes due to various hemodynamic anomalies, while in Group A a diamond shape was retained, indicating that all parameters were nearly normal (Fig 7). An unusual increase of the right heart volume in tricuspid insufficiency and enlargement of both right and left heart with prolongation of the pulmonary circulation time in mitral valve disease were characteristics frequently seen in Group B patients with combined valvular disease.

Discussion

Factors influencing long-term survival after valve replacement have been discussed by many authors[1,6,8-12,20,21,23] : 1) preoperative factors, such as NYHA Class, cardiac size, left ventricular hypertrophy or dysfunction, congestive heart failure and various hemodynamic parameters, 2) surgical factors, such as technique of myocardial protection, duration of cardiopulmonary bypass and residual uncorrected valvular disease, and 3) postoperative

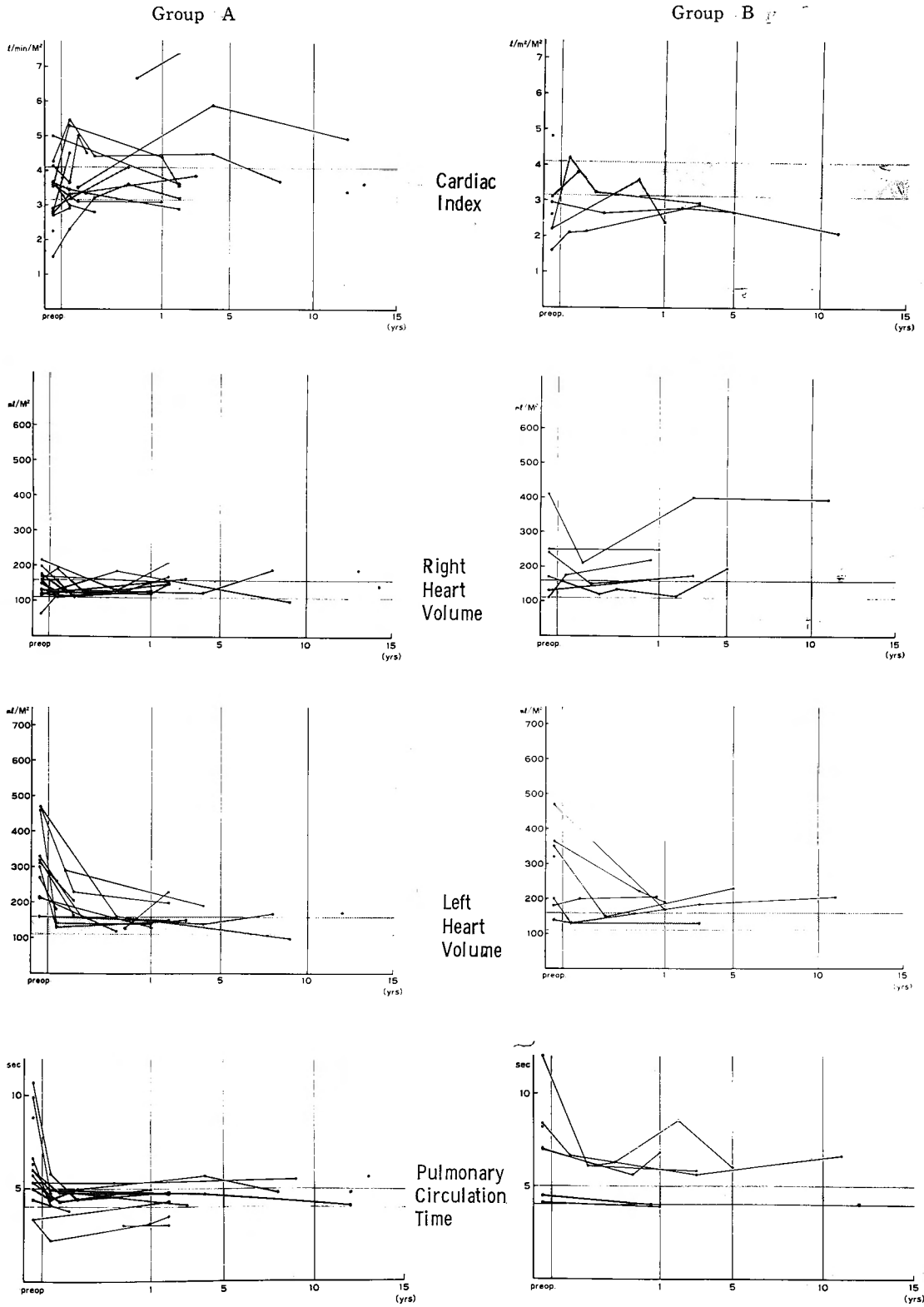

Fig. 5 Radiocardiographic follow-up data in isolated valvular disease. Normal values are shown by black shadows.

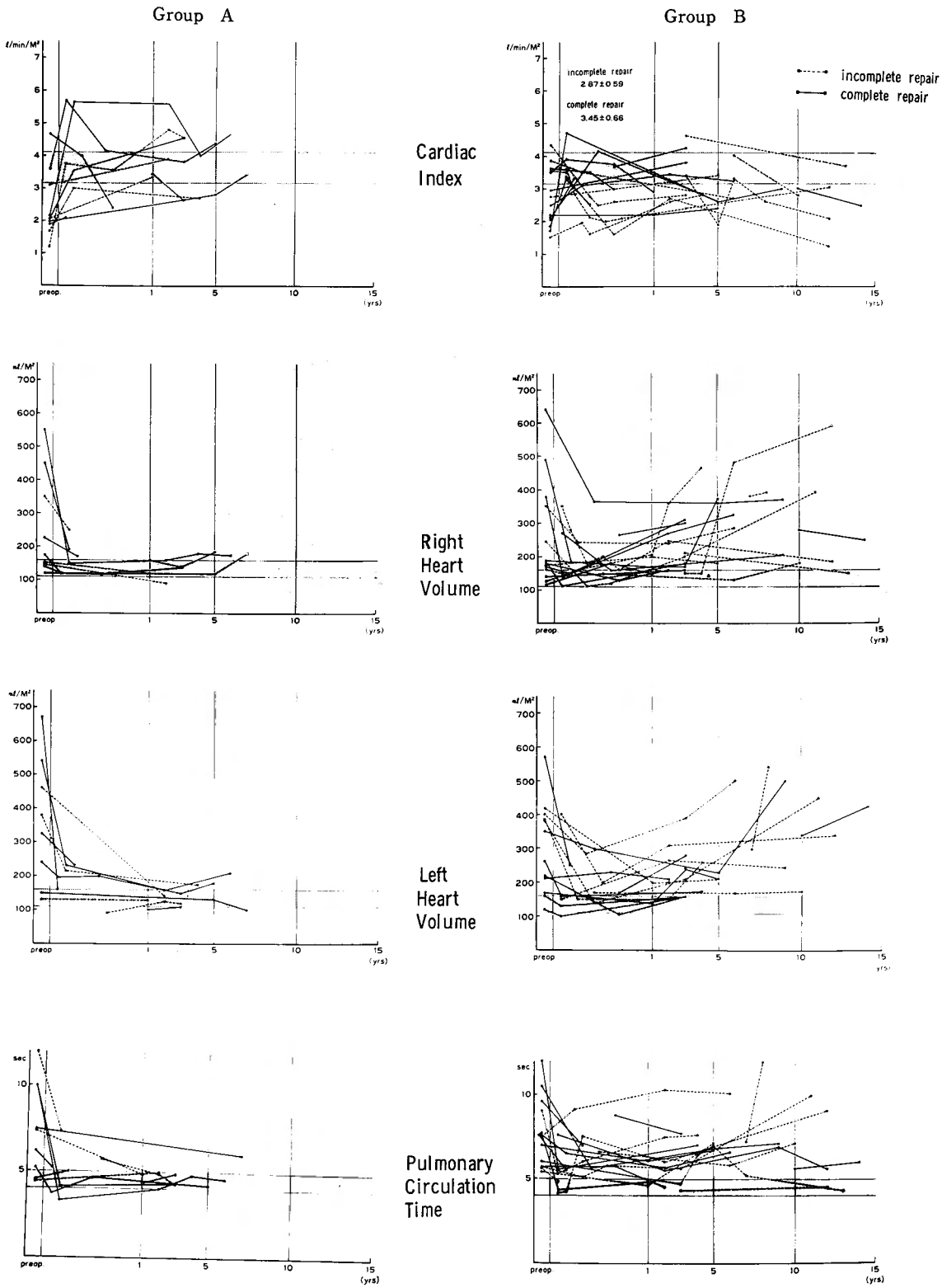

Fig. 6 Radiocardiographic follow-up data in combined valvular disease. Normal values are shown by black shadows.

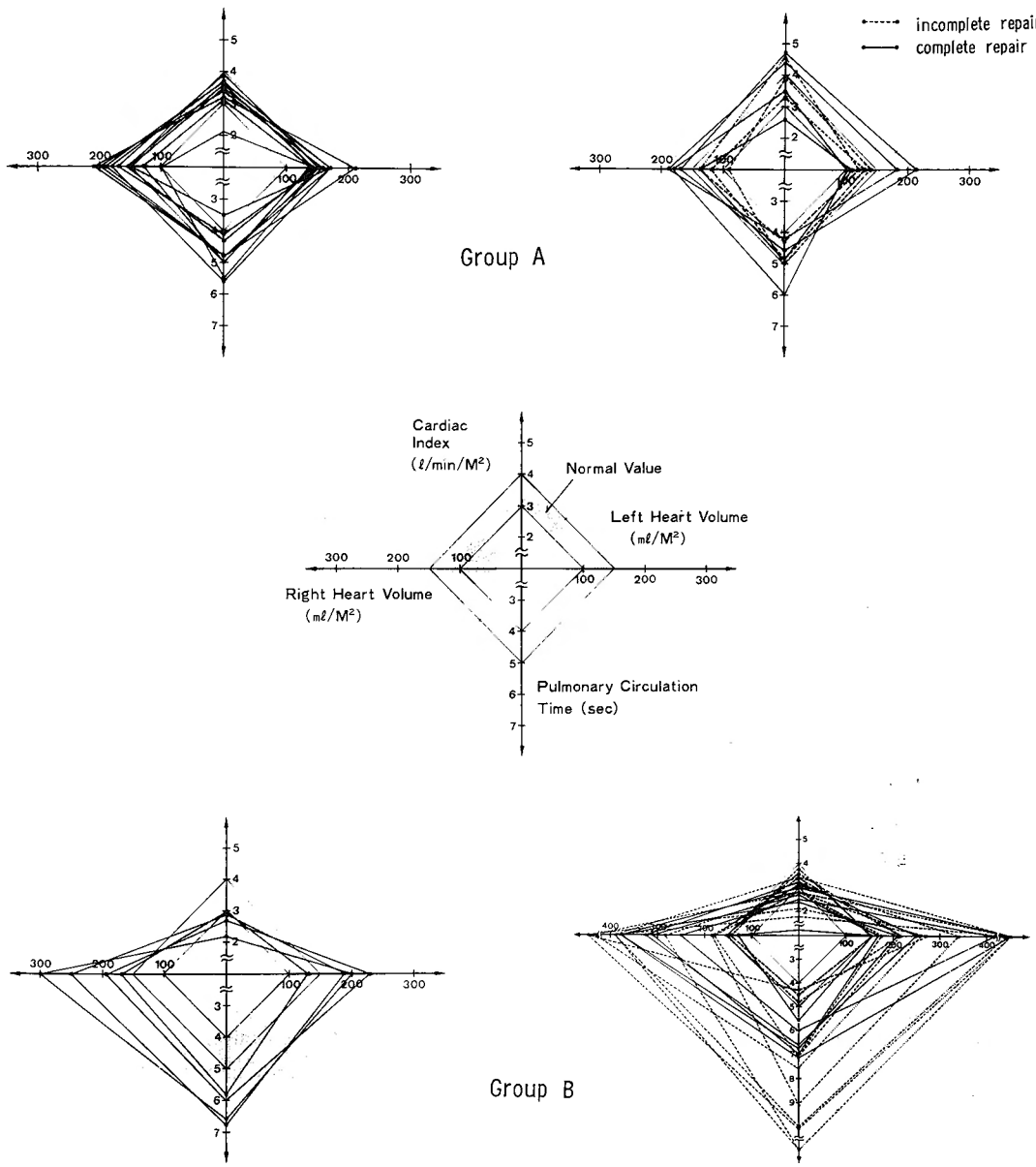

Fig. 7 Multivariable patterns of the latest radiocardiographic data for each patient.

complications, such as thromboembolism and malfunction of the prosthesis, On the other hand, factors influencing long-term functional status in surviving patients have rarely reported[5,22]. The present data indicate that the significant factors preventing complete recovery are: coexisting valvular lesions, atrial fibrillation, preoperative duration of symptoms and thromboembolism. Of these, multivalvular disease, especially if associated with atrial fibrillation and delayed surgery, has the greatest effect on both early and late functional

results.

Influence of coexisting tricuspid insufficiency : It is noteworthy that progressive tricuspid insufficiency significantly impaired cardiac function to NYHA Class III (Fig 3). The proper management of this disease in association with mitral valve disease remains controversial, partly because of the difficulty of evaluating the severity of tricuspid insufficiency. The only certain method may be inspection or palpation of the tricuspid valve at operation[24]. Tricuspid regurgitation which was not treated because it was considered to be minimal at the time of surgey worsened in four of the eight patients at various times postoperatively, although BRAUNWALD et al.[3] expected spontaneous regression of functional tricuspid regurgitation after correction of the mitral valve. Six patients with moderate to severe tricuspid insufficiency were treated by Boyd's annuloplasty, and two of them showed postoperative deterioration. For repair of the tricuspid valve, STARR[24], PLUTH[17], BREYER[4] and their associates have recommended valve replacement, while KAY[15], BOYD[2], REED[18] and their associates prefer annuloplasty. Our experience has demonstrated that annuloplasty by the obliteration of the posterior leaflet is not satisfactory from the standpoint of functional rehabilitation. We are now using DeVega's method[7] with good early results.

Influence of coexisting mitral valve disease : Progression of the mitral valvular lesion noted in four patients. In two of the three with uncorrected mitral regurgitation hemodynamically significant changes occurred during the follow-up period. Similar results were reported by KAMATA et al.[13] and ROBERT et al[19]. They stated that the aortic prosthesis probably created some degree of aortic stenosis which increased the amount of mitral regurgitation.

Influence of coexisting aortic insufficiency: Initial functional recovery in the patients with mitral valve replacement and associated uncorrected aortic regurgitation was not satisfactory. The aortic regurgitant stream may cause the mitral poppet to cock, creating considerable mitral prosthetic dysfunction[19], although we could not demonstrate it. On the contrary, the aortic valvular lesion was not a cause of late deterioration in our cases, as reported by KAMATA et al[13].

Influence of myocardial dysfunction : Myocardial dysfunction is a well recognized factor in poor functional results in survivors as well as a cause of early and late deaths. Myocardial abnormalities may be caused by long-standing rheumatic heart disease, poor myocardial preservation during surgery, coronary artery disease or thromboembolism. However, the evaluation of myocardial dysfunction is sometimes difficult in patients with multivalvular disease, because the hemodynamic effects of coexisting valvular disease may mask myocardial disease[9]. The poor functional rehabilitation in the patients with combined valvular disease in our study must also be related to myocardial factors. On the other hand, poor results in the patients with isolated valvular disease were due partly to coronary artery disease (2 cases) and to thromboembolism (1 case). Radiocardiograms in this group demonstrated a persistently low cardiac index as well as increase of the heart volumes even after successful valve replacement. These suggested the existence of myocardial dysfunction.

Influence of thromboembolism : Of 13 patients who had embolic episodes in spite of anticoagulation, one died from a clotted prosthesis and three others showed a deterioration of their functional status following embolism. However, physical examination and echocardiograms showed no clear evidence of a malfuntioning prosthesis. Further study will be needed in these patients to identify possible myocardial damage due to multiple coronary arterial emboli[9].

In order to improve functional results, earlier operation would seem to be indicated, since delay might lead to depression of myocardial function as well as to atrial fibrillation. Although the long-term prognosis for valve replacement in isolated valvular disease is good if the disease is not far-advanced, the treatment of multivalvular disease remains controversial. Complete repair of all diseased valves with appropriate techniques is reasonable. However, we do not believe that all mild coexising valvular lesions should be corrected by valve replacement, or even by valvoplasty, at the initial operation because of the relatively high mortality rate for multivalvular surgery[14]. At present, we can offer only palliation for patients with combined valvular disease. Close observation may show that a second operation should be done if the uncorrected valvular disease progresses significantly.

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和文抄録

大動脈および僧帽弁置換後の遠隔成績
——とくに術後機能に影響する因子について——

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弁置換後の遠隔成績は主として晩期死を中心に論ぜられることが多く，生存者の機能回復を中心問題として討論されることは比較的少ない．弁膜症の“根治”（無症状な状態で完全に社会復帰させる）を目的とするとき，NYHA Ⅱ度への復帰は決して満足されるものでなく，この意味では現在の弁置換術の成績はなお理想より遠い．我々は弁置換術後の完全回復（NYHA Ⅰ度）を妨げる因子の解明を目的として，術後1年以上生存した67人の弁置換患者（平均追跡期間6．8年）を対称として，アンケート調査および外来診察とくにRadiocardiography など利用して分析を行った．その結果，(1)症状発現より手術までの病悩期間，(2)心房細動，(3)合併弁膜症および(4)術後血栓症などが有意に術後機能回復に影響を及ぼすことが明らかになった．更に心筋因子も無視出来ないと思われ，早期手術の必要性が痛感された．